Explanation of ultra narrow-band reflection from a 1d grating based on a modal method and symmetry considerations

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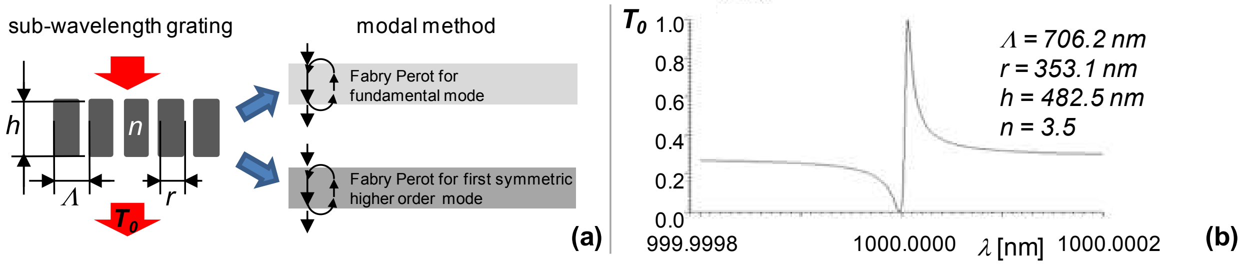
A 1D, high index contrast subwavelength binary corrugation can exhibit arbitrarily narrow reflection resonances. The necessary parameters are given analytically using the interference of the two involved grating modes and symmetry considerations of their reflection and transmission coefficients.

Introduction

A 1D, high index contrast subwavelength binary grating exhibits under normal incidence narrow reflection peaks characterized by a huge field accumulation in the high index corrugation [1]. The analysis in [2] attributes the resonance sharpness to the resonance of a super-mode, which is a particular combination of the two involved eigenmodes of the grating. Based on this idea, the present contribution will explain why those resonances can be infinitely narrow.



(a): Considered grating with parameter definition, (b): example of an extremely narrowband resonance

Summary

The occurrence of the narrowband resonances can be understood by considering the first two vertically propagating modes, created by the periodic refractive index variation of the grating (Fig. 1(a)). The resonances can be identified by the number of roundtrips m_0 and m_2 in the corresponding Fabry Perot resonators [3]. The interaction between the modes and their transmission to the outside can be described by transmission and reflection coefficients at the substrate-grating and grating-cover interface, while their propagation simply corresponds to a phaseshift. By using energy conservation at the interfaces and certain symmetry considerations, the ideal zero-width fano-type resonance is found if the following grating heights $h_{res,0}$ and $h_{res,1}$ are equal :

$$h_{res,0} = \left(m_0\pi + \arg\left(\frac{t_{c2}}{t_{c0}r_{02} - t_{c2}r_{00}} \right) \right) \Big/ 2\pi n_{eff,0} \qquad h_{res,2} = \left(m_2\pi + \arg\left(\frac{t_{c0}}{t_{c2}r_{02} - t_{c0}r_{22}} \right) \right) \Big/ 2\pi n_{eff,2}$$

(t_{cx} – transmission coeff. of mode x to cover and substrate; r_{xy} – reflection coeff. from mode x to y; $n_{eff,x}$ – effective index of mode $_x$). As will be shown in the presentation the equality of those two heights is systematically fulfilled for the considered grating structure, which explains the inevitable occurrence of ultra-narrowband resonances and allows the determination of their parameters in an exhaustive, analytic fashion.

References

[1] E. Bonnet et al., Opt. Quant. Electr., vol. 35, pp. 1025-1036 (2003)
[2] C. Hasnain et al., Adv. in Opt. and Phot., vol. 4, pp. 379 -439 (2012)
[3] O. Parriaux et al., Opt. Express, Vol. 20, pp. 28070-28081 (2012)